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# Ichthyofauna associated with sandy beaches of the rio Machado, tributary of the rio Madeira, northern Brazil

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**Abstract**

The rio Machado is an large tributary of the rio Madeira, and investigations of the ichthyofauna are urgent given the current high threat of habitat loss on account of a hydroelectric plant under construction. Our inventory quantified 9,544 specimens, representing four orders and 38 species. Our study provides an unprecedented list of fish species from a poorly studied South American basin. This basin, which is considered one of the world's biodiversity hotspots, presents high endemism, few cases of co-existence of phylogenetically related lineages, low species diversity, and few species occurrences with wide distribution.

**Keywords**

Amazon, inventory, Machado river basin, Neotropical region, species diversity

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## Introduction

River and floodplain systems, especially in tropical regions, hold a high diversity of freshwater fish (Lowe-McConnell 1987; Freitas et al. 2010; Queiroz et al. 2013). In northern Brazil, this high ichthyofaunal diversity is associated with the complex drainage system of the Amazon, which is formed by numerous types of habitats, such as anastomosed channels, floodplain lagoons, terra firme lakes, floodplain and igapó forests, marshes, streams, and beaches (e.g. Sioli 1984; Lowe-McConnel 1987, 1994).

Research on the freshwater ichthyofauna of benthic habitats has focused mainly on sandy beaches along the margins of rivers (Ibarra and Stewart 1989; Stewart et al. 2002), and the literature on Amazon fishes in sandy beaches is extremely scarce (Goulding et al. 1988; Ibarra and Stewart 1989; Jepsen et al. 1997; Stewart et al. 2002; Arrington and Winemiller 2003; Duarte et al. 2010, 2013; Carvalho et al. 2014; Silva et al. 2019). The scarcity of information on this subject is mainly due to the seasonality of the habitat: the vast majority of sandy beaches are

exposed only three months of the year (Santos and Ferreira 1999; Duarte et al. 2010).

According to Myers et al. (2000), the region where the rio Machado basin is inserted is considered one of the world's biodiversity hotspots. This bioregion is characterized by high endemism, few cases of co-existence of phylogenetically related lineages, low species diversity, and few occurrences of species with wide distribution (Dagosta et al. 2020). The rio Machado basin is one of eight regions in the Amazon basin that is recognized as rarely sampled, requiring immediate attention in taxonomic inventories to future stocks (Dagosta et al. 2020). Thus, in the present study we present a survey of the ichthyofauna associated with sandy beaches of the rio Machado, the main tributary of the rio Madeira right bank in the state of Rondônia, northern Brazil. This investigation becomes even more urgent and necessary due to such as the current construction of a hydroelectric plant.

## Study Area

The rio Machado is formed by the confluence of the rios Comemoração and Pimenta Bueno, and its drainage area covers 75,400 km$^2$. The Rio Machado is approximately 1,200 km in length and flows into the right bank of the rio Madeira (Krusche et al. 2005). The flood regime is characterized by rising water between November and December, and high-water between January and March, with the highest water level in February; the falling-water period is between April and July, while the low-water period occurs between August and October, and the minimum water level is observed in September (ANA 2019). Annual average rainfall is 2,500 mm (Krusche et al. 2005), and there are two distinct seasons: the dry season, from late May to September, and the rainy season from October to April (Fernandes and Guimarães 2002). The rio Machado basin has varied soils and land-uses. It varies from mostly unaltered habitats in the uppermost reach, near the two main tributaries, to considerable altered land use as it attains a channel width of up to 500 m in the middle course. The rio Machado receives several tributaries, such as the rios Rolim de Moura, Muqui, Riozinho, Tarumã, Urupá, Preto, and Jaru (Krusche et al. 2005). Regional climate is characterized by temperatures ranging from 19 to 33 °C.

## Methods

Freshwater fish were collected in September 2017 from 24 sandy beaches over an 81-km stretch of the rio Machado, with a mean interval of 4 km between sampling sites (Fig. 1). The physical conditions of some collection stations in the rio Machado basin are shown in Figure 2. We used a picaré trawl measuring 11 m in length by 6 m in height and with a 5-mm mesh between opposing knots to collect the specimens. Sampling took place during the day (06:00–17:00). The trawl was dragged parallel to the beach three times, totaling 72 samples.

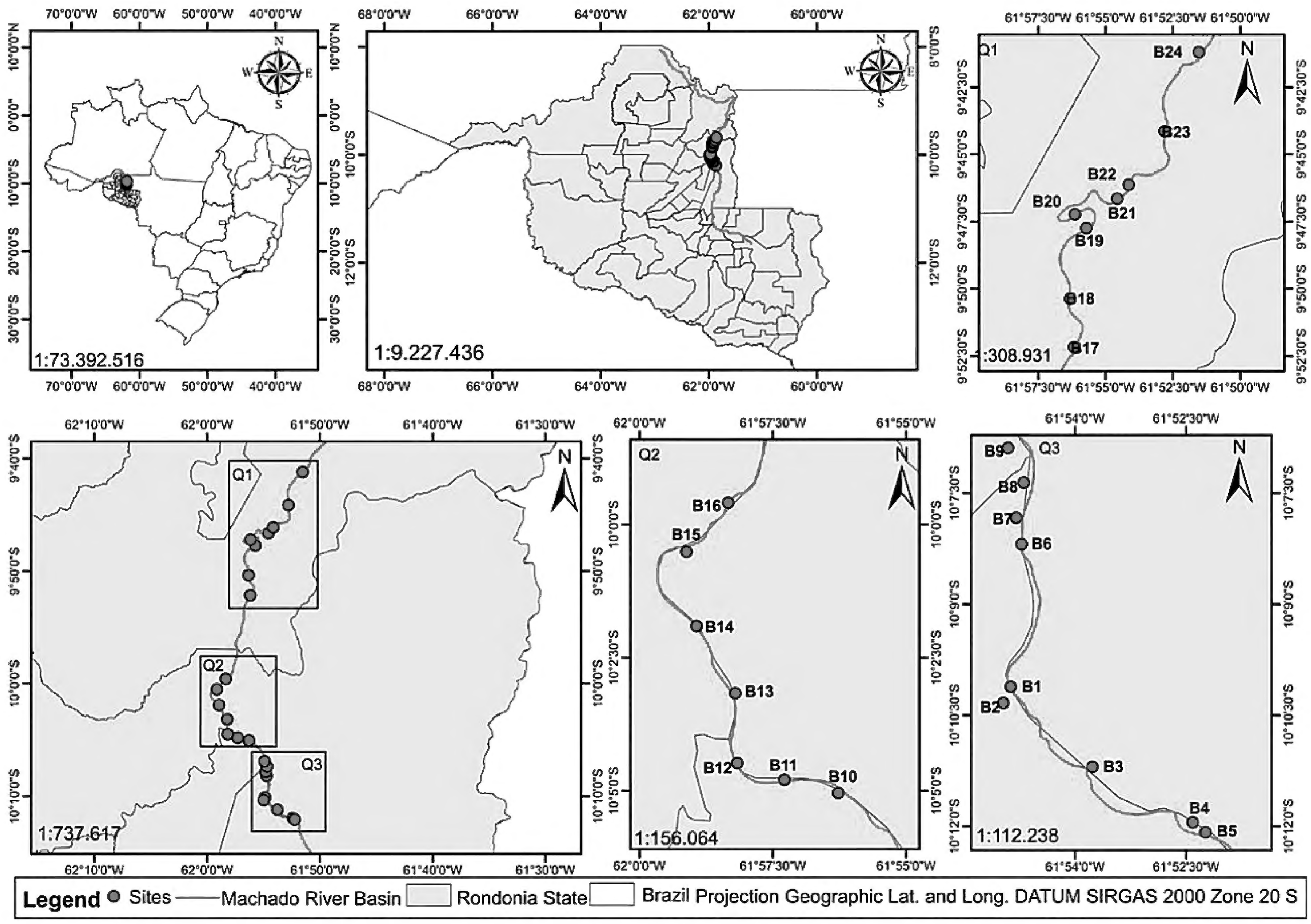


**Figure 1.** Map of the study area showing the collection stations in the drainage systems of the rio Machado basin, Rondônia, Brazil.

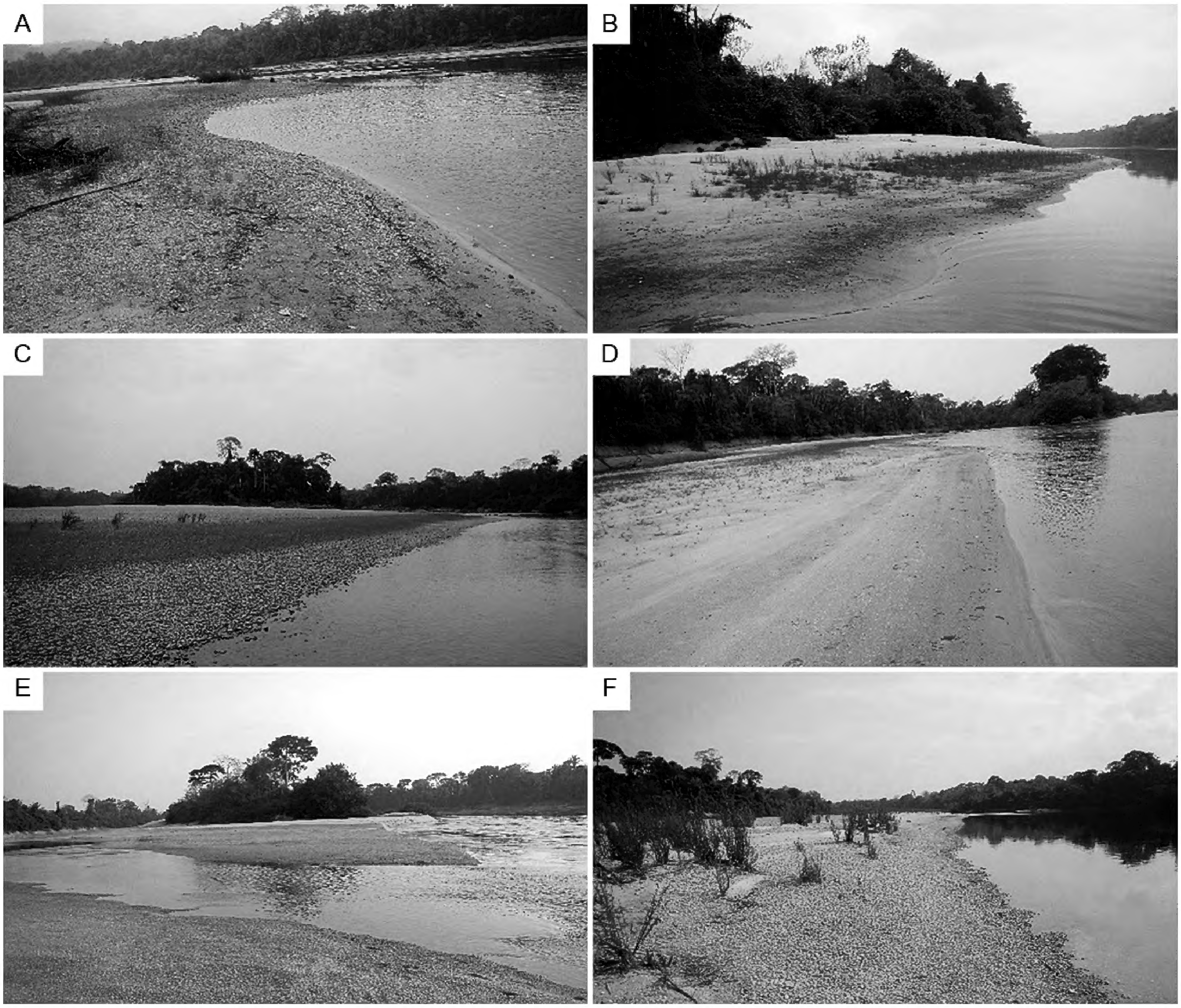


**Figure 2.** Habitats found in some of the collection stations along the rio Machado basin, Rondônia, Brazil. **A.** Beach 2 (B2). **B.** Beach 7 (B7). **C.** Beach 9 (B9). **D.** Beach 12 (B12). **E.** Beach 13 (B13). **F.** Beach 23 (B23).

Abiotic data, such as depth, beach shape, beach area, and substrate were observed *in situ*. Average depth was calculated from 20 measurements of depth, randomly obtained in each sampling site. The beach area ($m^2$) was calculated based on the beach shape (e.g. trapeze or ellipse) with a measuring tape. The physical structure of the substrate was determined by visually estimating the proportion of silt (<0.05 mm), sand (minimum diameter 0.05–2 mm), clay, rocks (diameter 2–10 cm), trunks (wood >10 cm in diameter), coarse litter (composed of leaves and small branches), fine litter (fine particulate matter), roots (tangled roots of riparian vegetation), and macrophytes (aquatic vegetation) (Table 1).

We sacrificed the specimens in a solution of clove oil (Eugenol, 2 drops per liter; cf. American Veterinary Medical Association 2001). The fish were then fixed in a 10% formalin solution and later preserved in 70% ethanol. Taxonomic literature and identification keys were consulted to identify species (Queiroz et al. 2013; Vieira et al. 2016; Ohara et al. 2017). The classification follows Nelson et al. (2016). The specimens were deposited in the Fish Collection of the National Museum of Brazil (MNRJ) and the Zoology Museum of the University of São Paulo, Brazil (MZUSP). Fish sampling was authorized by the Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio, license 47345-1/2014).

To evaluate representativeness in the inventory, species richness was estimated using a sample-based accumulation curve, with 9,999 permutations of the abundance matrix, with rows corresponding to sites and columns to species. We used the Jackknife 1 estimator to obtain the expected richness. This analysis was run in EstimateS (Colwell and Elsensohn 2014).

## Results

A total of 9,544 specimens were sampled, representing four orders, 12 families, 32 genera, and 38 species (Table 2). Characiformes, Cichliformes, Siluriformes, and Clupeiformes represented 79% (30 species), 10% (4 species), 8% (3 species), and 3% (1 species) of all species, respectively. Characiformes was the order with highest abundance (97%, $n$ = 9,254), followed by Cichliformes, Clupeiformes, and Siluriformes, with abundance values lower than 3% ($n$ = 273), 0.1% ($n$ = 12), and 0.1% ($n$ = 5),

**Table 1.** Sampling sites in beaches from the rio Machado basin with geographic coordinates, beach shape (BS), altitude, depth, beach area (BA) and substrate.

| Site | Geographic coordinates | BS | Altitude (m) | Depth (cm) | BA (m²) | Substrate |
|---|---|---|---|---|---|---|
| B1 | 10°10′07″S, 061°54′52″W | Trapeze | 123 | 74 | 311 | Sand |
| B2 | 10°10′20″S, 061°54′58″W | Ellipse | 123 | 51 | 842 | Sand |
| B3 | 10°11′12″S, 061°53′46″W | Ellipse | 123 | 35 | 1627 | Rounded rocks |
| B4 | 10°11′57″S, 061°52′24″W | Ellipse | 125 | 30 | 3354 | Sand |
| B5 | 10°12′05″S, 061°52′14″W | Ellipse | 122 | 36 | 805 | Rounded rocks |
| B6 | 10°08′11″S, 061°54′43″W | Ellipse | 76 | 28 | 1102 | Rounded rocks |
| B7 | 10°07′50″S, 061°54′47″W | Ellipse | 85 | 40 | 731 | Sand |
| B8 | 10°07′21″S, 061°54′41″W | Ellipse | 98 | 44 | 3603 | Sand |
| B9 | 10°06′53″S, 061°54′54″W | Ellipse | 72 | 37 | 1041 | Sand |
| B10 | 10°05′02″S, 061°56′16″W | Ellipse | 72 | 41 | 1228 | Rounded rocks |
| B11 | 10°04′47″S, 061°57′17″W | Ellipse | 109 | 41 | 1272 | Sand |
| B12 | 10°04′28″S, 061°58′10″W | Ellipse | 109 | 41 | 867 | Rounded rocks |
| B13 | 10°03′10″S, 061°58′12″W | Ellipse | 107 | 22 | 31752 | Rounded rocks |
| B14 | 10°01′54″S, 061°58′56″W | Ellipse | 112 | 45 | 16122 | Sand |
| B15 | 10°00′31″S, 61°59′07″W | Ellipse | 115 | 22 | 2883 | Sand |
| B16 | 09°59′35″S, 061°58′20″W | Rectangle | 106 | 51 | 138 | Sand |
| B17 | 09°52′09″S, 061°56′10″W | Ellipse | 74 | 44 | 1429 | Rounded rocks |
| B18 | 09°50′22″S, 061°56′19″W | Ellipse | 68 | 12 | 19983 | Sand |
| B19 | 09°47′45″S, 061°55′43″W | Ellipse | 79 | 21 | 10108 | Sand |
| B20 | 09°47′13″S, 061°56′08″ W | Ellipse | 74 | 28 | 7748 | Sand |
| B21 | 09°46′38′S, 061°54′34″W | Ellipse | 88 | 25 | 3729 | Sand |
| B22 | 09°46′08″S, 061°54′08″W | Ellipse | 82 | 21 | 69237 | Rounded rocks |
| B23 | 09°44′09″S, 061°52′48″W | Ellipse | 104 | 55 | 16234 | Sand |
| B24 | 09°41′12″S, 061°51′32″W | Ellipse | 111 | 16 | 779 | Silt |

**Table 2.** Fish captured in sandy beaches along the rio Machado, Rondônia, in September 2017, with their abundance (*N*) and catalogue number of voucher specimens. * Potential for the ornamental fish trade (Brasil 2012). Systematic positions were based on Nelson et al. (2016).

| Class/order/family/species | *N* | Voucher |
|---|---|---|
| Osteichthyes | | |
| Clupeiformes | | |
| Engraulidae | | |
| *Anchoviella juruasanga* Loeb, 2012 | 12 | MZUSP 124838 |
| Characiformes | | |
| Anostomidae | | |
| *Leporinus* cf. *cylindriformis* Borodin, 1929 | 1 | MNRJ 51432 |
| *Leporinus friderici* (Bloch, 1794) | 1 | MNRJ 51425 |
| Characidae | | |
| *Astyanax* cf. *elachylepis* Bertaco & Lucinda, 2005 | 3 | MNRJ 51428 |
| *Brycon* aff. *pesu* Müller & Troschel, 1845 | 2 | MNRJ 51440 |
| *Bryconops* cf. *caudomaculatus* (Günther, 1864)* | 203 | MZUSP 124833 |
| *Bryconops* cf. *giacopinii* (Fernández-Yépez, 1950) | 60 | MZUSP 124830 |
| *Creagrutus anary* Fowler, 1913 | 44 | MZUSP 124834 |
| *Creagrutus maxillaris* (Myers, 1927) | 2 | MZUSP 124843 |
| *Creagrutus* sp. | 5 | MNRJ 51436 |
| *"Deuterodon"* sp. | 3 | MZUSP 124841 |
| *Hemigrammus* cf. *geisleri* Zarske & Géry, 2007 | 10 | MZUSP 124836 |
| *Jupiaba zonata* (Eigenmann, 1908)* | 22 | MZUSP 124852 |
| *Knodus* cf. *heteresthes* (Eigenmann, 1908) | 8258 | MZUSP 124835 |
| *Microschemobrycon callops* Böhlke, 1953* | 5 | MNRJ 51437 |
| *Moenkhausia oligolepis* (Günther, 1864)* | 7 | MZUSP 124846 |
| *Moenkhausia collettii* (Steindachner, 1882)* | 22 | MNRJ 51430 |
| *Moenkhausia rondoni* Mathubara & Toledo-Piza, 2020* | 58 | MZUSP 124853 |
| *Moenkhausia hasemani* Eigenmann, 1917* | 6 | MZUSP 124831 |
| *Phenacogaster* cf. *pectinatus* (Cope, 1870) | 1 | MNRJ51426 |
| *Phenacogaster* cf. *retropinnus* Lucena & Malabarba, 2010 | 5 | MNRJ51439 |
| *Poptella compressa* (Günther, 1864) | 1 | MZUSP 124848 |
| *Serrapinnus* aff. *notomelas* (Eigenmann, 1915) | 17 | MNRJ 51433 |
| *Serrapinnus micropterus* (Eigenmann, 1907) | 10 | MZUSP 124842 |
| *Tetragonopterus argenteus* Cuvier, 1816* | 2 | MNRJ 51427 |
| Crenuchidae | | |
| *Characidium* aff. *zebra* Eigenmann, 1909 | 1 | MNRJ 51431 |
| Ctenoluciidae | | |
| *Boulengerella cuvieri* (Spix & Agassiz, 1829) | 1 | MNRJ 51434 |
| Curimatidae | | |
| *Cyphocharax spiluropsis* (Eigenmann & Eigenmann, 1889) | 3 | MZUSP 124845 |
| Hemiodontidae | | |
| *Bivibranchia fowleri* (Steindachner, 1908) | 137 | MZUSP 124849 |
| Parodontidae | | |
| *Apareiodon* sp. | 364 | MZUSP 124844 |
| Siluriformes | | |
| Callichthyidae | | |
| *Corydoras armatus* (Günther, 1868)* | 1 | MZUSP 124850 |
| Loricariidae | | |
| *Spatuloricaria evansii* (Boulenger, 1892)* | 1 | MZUSP 124837 |
| Trichomycteridae | | |
| *Vandellia cirrhosa* Valenciennes, 1846 | 3 | MNRJ51438 |
| Cichliformes | | |
| Cichlidae | | |
| *Crenicichla santosi* Ploeg, 1991 | 15 | MZUSP 124840 |
| *Crenicichla* sp. | 1 | MNRJ 51429 |
| *Geophagus* sp. | 248 | MZUSP 124851 |
| *Satanoperca jurupari* (Heckel, 1840)* | 9 | MZUSP 124839 |

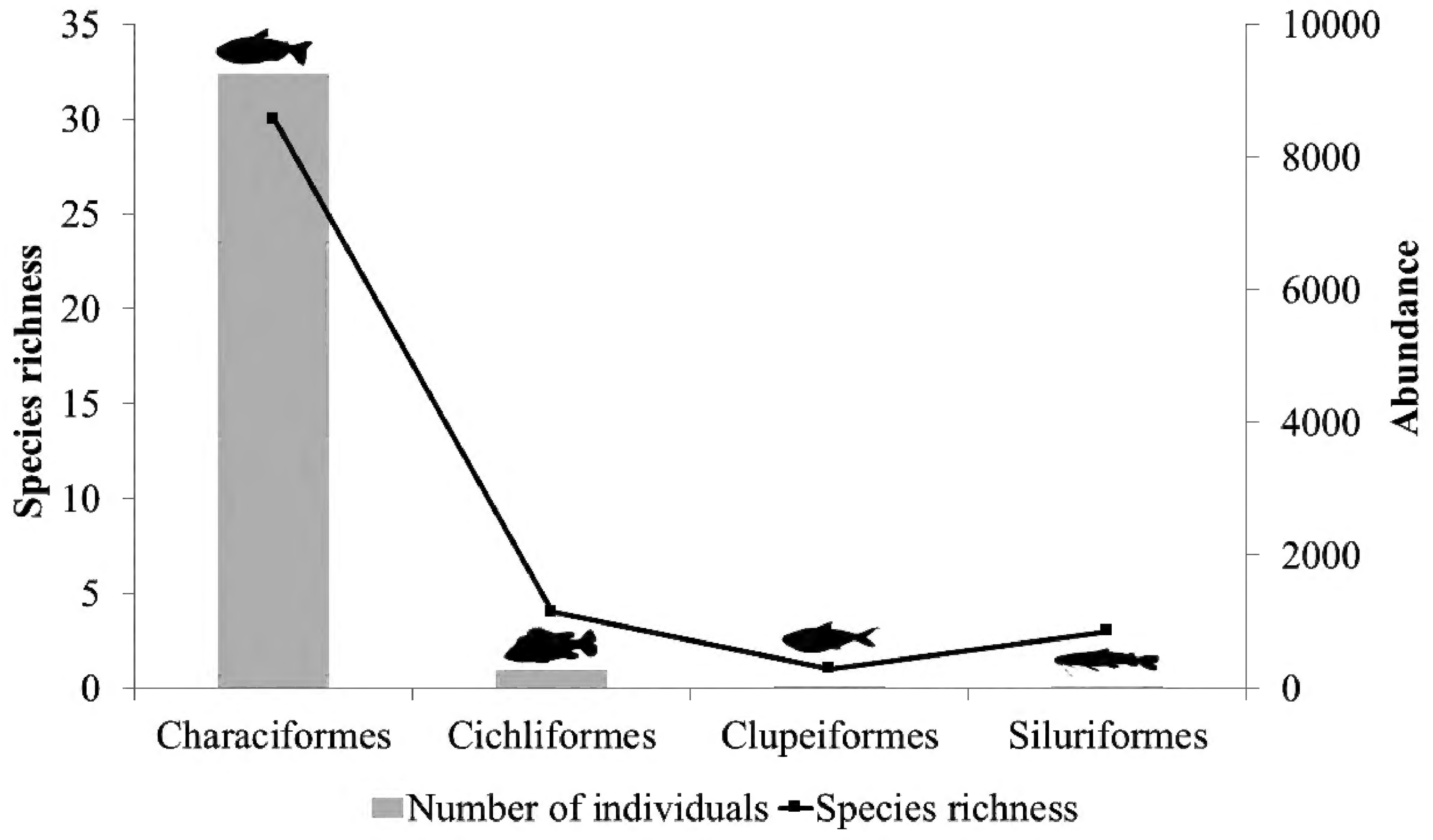


**Figure 3.** Species abundance and richness of fish orders collected in sandy beaches along the rio Machado, Rondônia, Brazil.

respectively (Fig. 3). The family with the highest richness and abundance was Characidae (23 species, 59%; *n* = 8,746, 91%), followed by Cichlidae (10%, 4 species) and Anostomidae (5%, 2 species). The Parodontidae family was the second most representative (4%, *n* = 364), followed by Cichlidae (3%, *n* = 273). The other families showed richness and abundance lower than 3% (Fig. 4). *Knodus* cf. *heteresthes* (Eigenmann, 1908) (*n* = 8,258), *Apareiodon* sp. (*n* = 364), *Geophagus* sp. (*n* = 248), and *Bryconops* cf. *caudomaculatus* (Günther, 1864) (*n* = 203) were the most abundant species among the total specimens collected in the sandy beaches.

The species richness (38 species) represented 76.52% of the richness estimated by Jackknife 1 (50 ± 4 species). The accumulation curve shows a tendency for stabilization, but it did not reach an asymptote, indicating that even more species would be recorded with increased sampling effort (Fig. 5).

The beaches with the most diverse fish fauna were B14 and B17, each with 15 species, followed by B10 (13 species), and B8 and B11, each with 12 species. The sites with the greatest abundance of fish were B20 (*N* = 1,481 individuals), B18 (*N* = 815), B15 (*N* = 730), and B21 (*N* = 544), respectively (Fig. 6).

# Discussion

Several studies have been conducted regarding the fish associated with sandy beaches in different parts of the Amazon basin in Brazilian territory. These assessments have reported 248 species in beach environments of the rio Negro (Lowe-McConnell 1989; Goulding 1997), 119 species in beaches of the rio Madeira (Py-Daniel et al. 2007), 112 species in beach environments along the rio

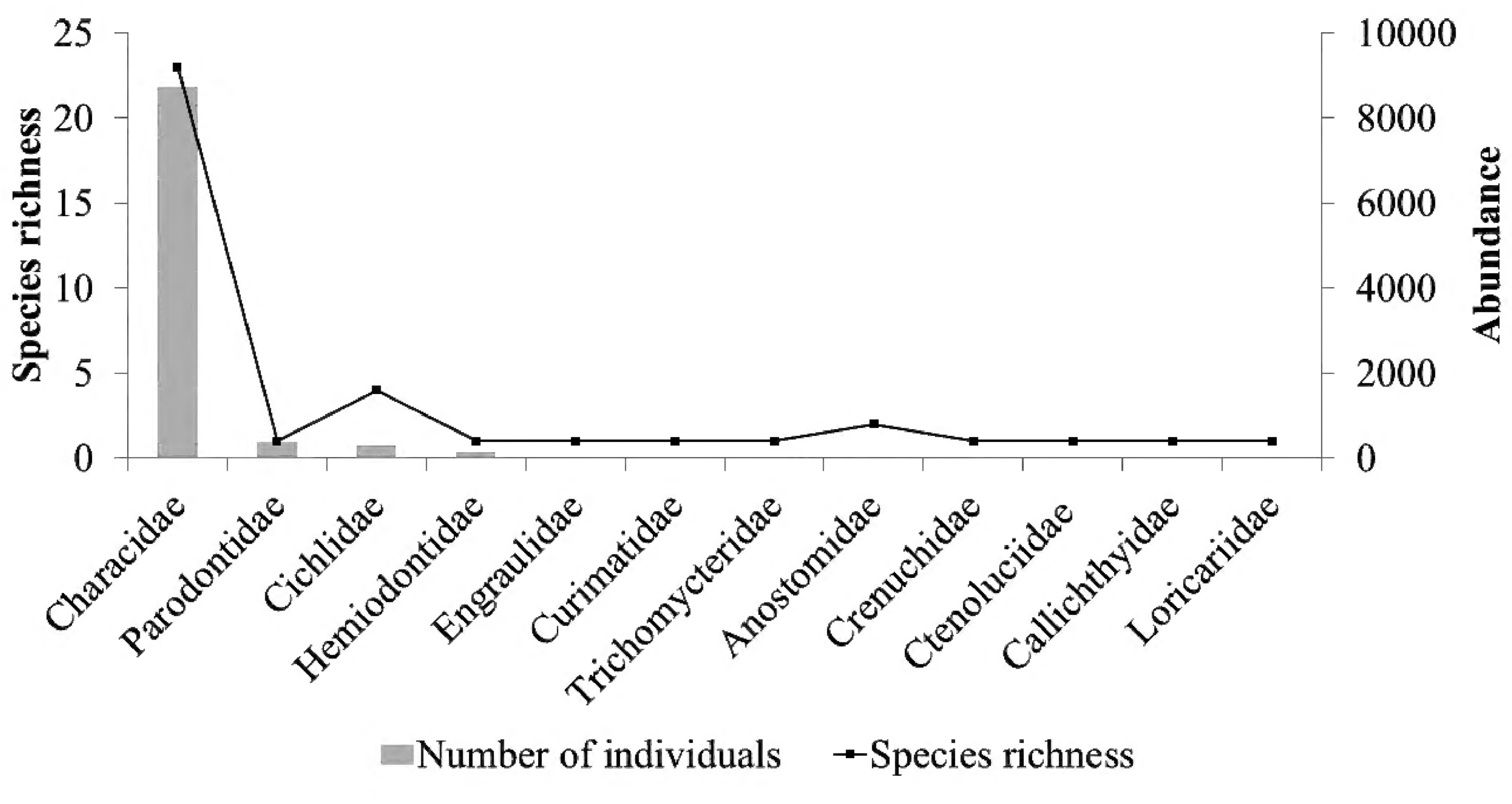


**Figure 4.** Species abundance and richness of fish families collected in sandy beaches along the rio Machado, Rondônia, Brazil.

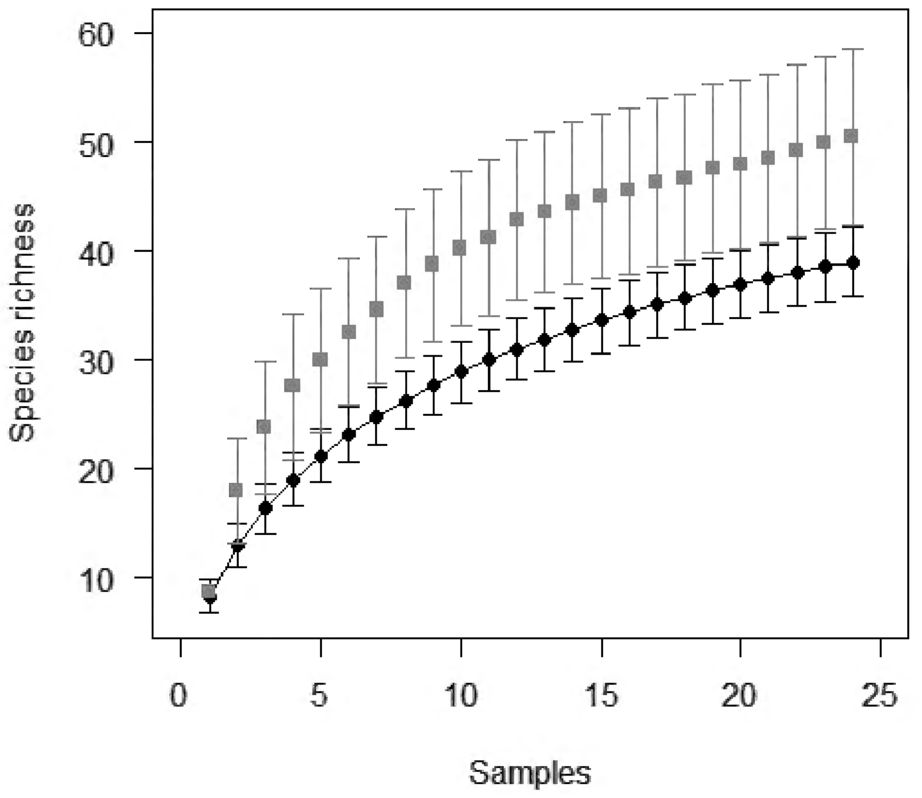


**Figure 5.** Species accumulation curve for the fish collected from sandy beaches of the rio Machado, Rondônia, Brazil. Square = Jackknife 1; circle = richness observed. The bars represent the confidence interval.

Purus (Stewart et al. 2002; Duarte et al. 2010), 90 species in the upper rio Juruá (Silvano et al. 2001), and 80 species in the rio Acre (Silva et al. 2020). The relatively low number of species sampled in the present study can be partially explained by the short sampling period, the use of a single method of capture, which is selective for species with reduced swimming ability (small characids) (Silva et al. 2020), and the absence of sample collections at night. The stretch sampled in our study presented a high population density of caimans (*Melanosuchus niger* and *Caiman crocodilos* species), which did not enable conditions for night sampling. The use of various collection methods is essential to increase the representativity of species richness at our sites, since species have different swimming abilities and occur in different beach habitats (Duarte et al. 2010). However, despite the low species richness, we highlight that our survey resulted in novel data for the rio Machado basin, the voucher material will allow further taxonomic studies, and our results contribute to an increasing body of knowledge on Amazon ichthyofauna.

Specimens of the order Characiformes were the most representative in abundance and number of species, which is consistent with the prevalence previously noted for several Neotropical freshwater habitats (Lowe-McConnell 1999; Dagosta and de Pinna 2019). As reported in earlier studies, small characids are the dominant group in sandy beaches (Jepsen 1997; Duarte et al. 2010), a condition which is associated with their ability to use oxygen near the water column surface (Silva et al. 2020), high trophic plasticity (Abelha et al. 2001), and extensive distribution in the Neotropical region (Pouilly et al. 2004). The Siluriformes group also shares high diversity with the Characiformes (Reis et al. 2016). However, the reduced number of individuals and species in our research is due to the absence of night sampling. Fish guided by chemical, electrical, or tactile stimuli, such as Siluriformes, are more active at night and mostly found in turbid waters (Matthews 1998).

Regarding the abundance of characids, particularly *Knodus* cf. *heteresthes*, this could be related to their broad diets and high trophic plasticity (Nogueira and Costa 2014). According to Rezende and Mazzoni (2003), many characid species are opportunistic in their use of food resources in various environments, and this demonstrates that some species are likely to use a given type of food item in the absence of another that would have been preferred. Most teleost fishes in tropical rivers have notable versatility in their feeding habits, which is a remarkable aspect of tropical rivers (Lowe-McConnell 1999; Correa and Winemiller 2014). This trophic versatility can be related to spatial, seasonal and human changes in habitats, which influence abiotic conditions (e.g. oxygen

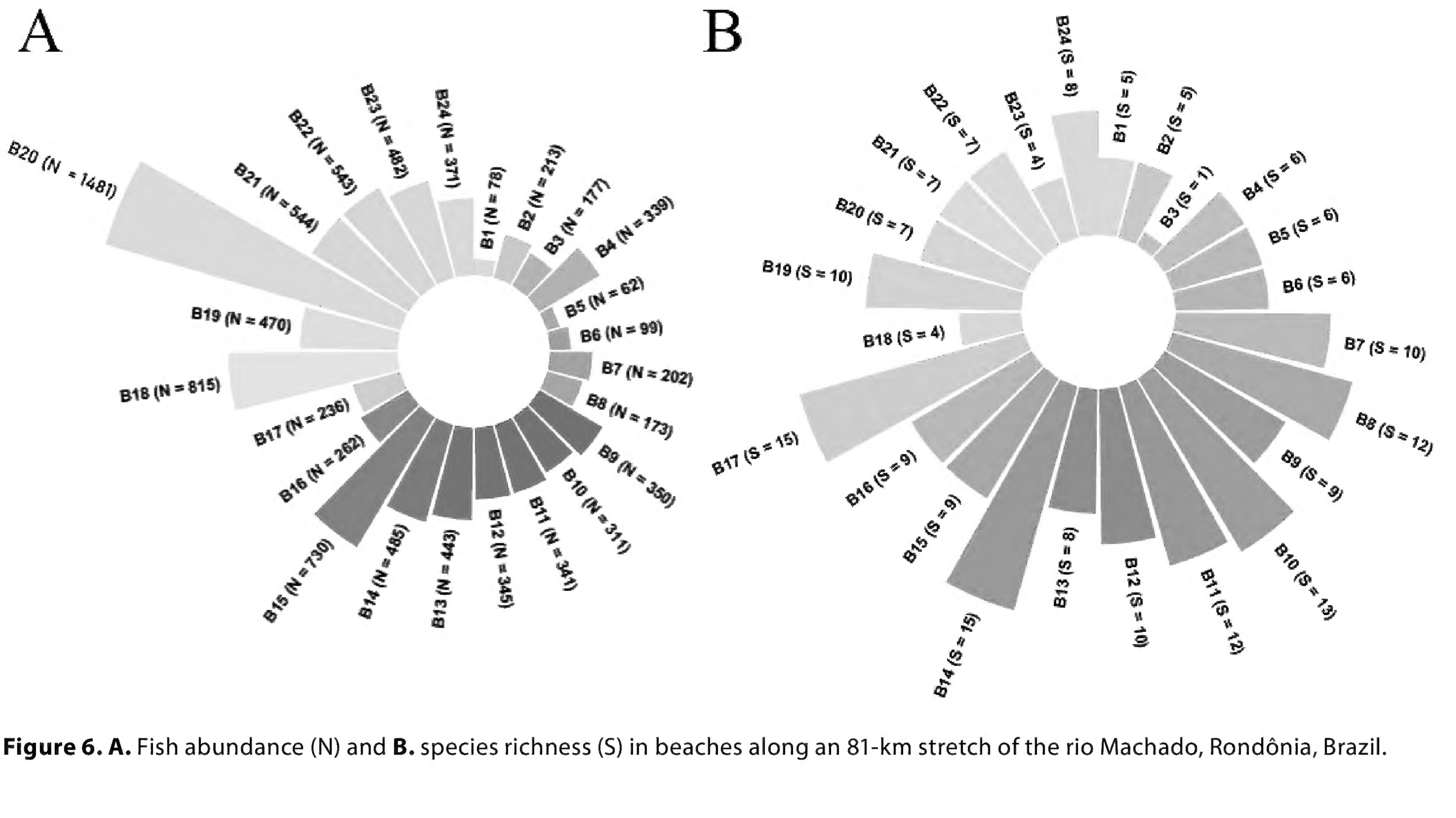


**Figure 6. A.** Fish abundance (N) and **B.** species richness (S) in beaches along an 81-km stretch of the rio Machado, Rondônia, Brazil.

concentration, temperature, pH) and food availability (Whitehouse et al. 2017), forcing species to adapt to different environments and resulting in a broad diet spectrum among most teleosts (Silva et al. 2020).

Approximately 36% (11 species) of the species sampled from the rio Machado beaches are listed as ornamental fish (Regulatory Directive 001/2012- MPA/MMA) (Brasil 2012). Some of these species, such as *Bryconops* cf. *caudomaculatus*, *Moenkhausia collettii*, and *M. rondoni* (Table 2), were well represented in our investigation, suggesting high abundance. With the development and execution of adequate management measures, ornamental fish could be explored as a source of income for the local population.

The species accumulation curve indicated that the maximum number of species in the beaches sampled may not have been reached, since the curve did not reach an asymptote. Sampling efficiency at 76% indicates that the richness observed is in agreement with the values of the species estimator, which revealed a possible variation in species richness in the study site. Nevertheless, the result of the estimation analysis (Jackknife 1) indicated that we were close to the "real" number of species. It is possible that if samples had been taken from more beaches and during the night period, more species that are commonly found in this portion of the river basin would have been captured.

The various species classified only to the genus level, and the use of "cf." or "aff.", are indications that the number of new species may be greater. Several species, namely, *Hemigrammus* cf. *geisleri* Zarske & Géry, 2007, *Phenacogaster* cf. *pectinatus* (Cope, 1870), *Phenacogaster* cf. *retropinnus* Lucena & Malabarba, 2010, *Characidium* aff. *zebra* Eigenmann, 1909, *Corydoras* cf. *armatus* Günther, 1868, and *Crenicichla* sp. belong to poorly known or even undescribed groups, and more taxonomic studies are needed.

Some studies have reported higher fish diversity in sandy beaches than in other habitats, such as streams, rivers, lakes, and floating vegetation (Lowe-McConnell 1989, Py-Daniel et al. 2007). The nutrient dynamics and availability of habitats in beach environments directly influence the energy flow and favor species richness (Roach and Winemiller 2015). Moreover, the physical and structural aspects of beaches, such as the presence of backwater areas, high clarity and luminosity of water, and shallow depths favor the presence of small and juvenile specimens of larger species that use this habitat as a refuge from predators (Arrington and Winemiller 2003) and for foraging (Lowe-McConnell 1999; Duarte et al. 2010). Thus, promoting an increase in the available information about ichthyofauna diversity in sandy beaches is important not only for future research investigating fish biodiversity on a macroscale, but also in the development of mitigating actions on the impacts on the biological integrity of a region surrounded by a long history of anthropogenic disturbances (deforestation, gold mining, highway construction, and most recently the building of a large hydroelectric plant).

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## Authors' Contributions

Conceptualization: IDC, NNSN. Data curation: IDC. Formal analysis: IDC. Investigation: IDC, NNSN. Methodology: IDC, NNSN. Supervision: IRZ. Validation: IDC. Visualization: NNSN Writing – original draft: IDC Writing – review and editing: IRZ.

## References

Abelha MCF, Agostinho AA, Goulart E (2001) Plasticidade trófica em peixes de água doce. Acta Scientiarum 23 (2): 425–434. https://doi.org/10.4025/actascibiolsci.v23i0.2696

American Veterinary Medical Association (2001) Report of the AVMA panel on euthanasia. Journal of the American Veterinary Medical Association 218 (5): 669–696.

ANA (Agência Nacional de Águas) (2019) http://hidroweb.ana.gov.br/. Agência Nacional de Águas, Ministério do Desenvolvimento Regional, Brasilia, Brasil. Acessed in: 2019-10-02.

Arrington DA, Winemiller KO (2003) Diel changeover in sandbank fish assemblages in a Neotropical floodplain river. Journal of Fish Biology 63 (2): 442–459. https://doi.org/10.1046/j.1095-8649.2003.00167.x

Brasil (2012) Ministério da Pesca e Aquicultura, Ministério do Meio Ambiente. Instrução Normativa Interministerial nº 1, de 03 de Janeiro de 2012. Estabelece normas, critérios e padrões para a explotação de peixes nativos ou exóticos de águas continentais com finalidade ornamental ou de aquariofilia. Poder executivo, Brasília, DF, 2012-03-01.

Carvalho MS, Zuanon J, Ferreira EJ (2014) Diving in the sand: the natural history of *Pygidianops amphioxus* (Siluriformes: Trichomycteridae), a miniature catfish of Central Amazonian streams in Brazil. Environmental Biology of Fishes 97 (1): 59–68. https://doi.org/10.1007/s10641-013-0123-9

Colwell RK, Elsensohn JE (2014) EstimateS turns 20: statistical estimation of species richness and shared species from samples, with non-parametric extrapolation. Ecography 37 (6): 609–613.

Correa SB, Winemiller KO (2014) Niche partitioning among frugivorous fishes in response to fluctuating resources in the Amazonian floodplain forest. Ecology 95 (1): 210–224. https://doi.org/10.1890/13-0393.1

Dagosta FC, De Pinna M (2019) The fishes of the Amazon: distribution and biogeographical patterns, with a comprehensive list of species. Bulletin of the American Museum of Natural History 2019 (431): 1–163. https://doi.org/10.7910/dvn/zkczjs

Dagosta FC, de Pinna M, Peres CA, Tagliacollo VA (2021) Existing protected areas provide a poor safety-net for threatened Amazonian fish species. Aquatic Conservation: Marine and Freshwater Ecosystems 31 (5): 1167–1189. https://doi.org/10.1002/aqc.3461

Duarte C, Deus CPD, Py-Daniel LR (2013) Comparação da eficiência relativa de dois apetrechos de coleta de peixes em praias no baixo

rio Purus, Amazonas, Brasil. Acta Amazonica 43 (3): 383–387.

Duarte C, Py-Daniel LHR, Deus CPD (2010) Fish assemblages in two sandy beaches in lower Purus river, Amazonas, Brazil. Iheringia. Série Zoologia 100 (4): 319–328.

Fernandes LC, Guimarães SCP (2002) Atlas geoambiental de Rondônia. SEDAM, Porto Velho, Brazil, 50 pp.

Freitas CEDC, Siqueira-Souza FK, GuimarãesR, Santos FA, Santos IL (2010) Interconnectedness during high water maintains similarity in fish assemblages of island floodplain lakes in the Amazonian Basin. Zoologia 27 (6): 124–131.

Goulding M (1997) História natural dos rios amazônicos. Sociedade Civil Mamirauá, Belém, Brazil, 139 pp.

Goulding M, Carvalho ML, Ferreira EG (1988) Rio Negro, rich life in poor water. Amazonian diversity and foodchain ecology as seen through fish communities. SPB Academic Publishing, the Hague, the Netherlands, 172 pp.

Ibarra M, Stewart DJ (1989) Longitudinal zonation of sandy beach fishes in the Napo River basin, eastern Ecuador. Copeia 14 (2): 364–381. https://doi.org/10.2307/1445433

Jepsen DB (1997) Fish species diversity in sand bank habitats of a Neotropical river. Environmental Biology Fishes 49: 449–460. https://doi.org/10.1023/A:1007371132144

Krusche AV, Ballester MVR, Victoria RL, Bernardes MC, Leite NK, Hanada L, Gomes BM (2005) Efeitos das mudançass do uso da terra na biogeoquímica dos corpos d'água da bacia do rio Ji-Paraná, Rondônia. Acta Amazonica 35: 197–205. https://doi.org/10.1590/S0044-59672005000200009

Lowe-McConnell R (1989) Rio Negro, rich life in poor water: Amazonian diversity and foodchain ecology as seen through fish communities. SPB Academic Publishing, the Hague, the Netherlands, 200 pp.

Lowe-McConnell RH (1994) Threats to, and conservation of, tropical freshwater fishes. Internationale Vereinigung für Theoretische und Angewandte Limnologie: Mitteilungen 24 (1): 47–52. https://doi.org/10.1080/05384680.1994.11904024

Lowe-McConnell RH (1987) Ecological studies in tropical fish communities. Cambridge Tropical Biology Series. Cambridge University Press, Cambridge, UK, 382 pp.

Lowe-McConnell RH (1999) Estudos ecológicos de comunidades de peixes tropicais. EDUSP, Paulo, Brazil, 535 pp.

Matthews WJ, Robison HW (1998) Influence of drainage connectivity, drainage area and regional species richness on fishes of the interior highlands in Arkansas. The American Midland Naturalist 139 (1): 1–19. https://doi.org/10.1674/0003-0031(1998)139[0001:iodcda]2.0.co;2

Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GAB, Kent J (2000) Biodiversity hotspots for conservation priorities. Nature 403: 853–858. https://doi.org/10.1038/35002501

Nelson JS, Grande TC, Wilson MV (2016) Fishes of the world, fifth edition. John Wiley & Sons, Hoboken, USA, 752 pp.

Nogueira WV, Costa ID (2014) Aspectos da alimentação de *Knodus heteresthes* (Characiformes, Characidae) no igarapé do Nove, bacia do rio Machado, Rondônia, Brasil. Biotemas 27 (3): 97–108. https://doi.org/10.5007/2175-7925.2014v27n3p97

Ohara WM, Lima FCT, Salvador GN, Andrade MC (2017) Peixes do Rio Teles Pires: diversidade e guia de identificação. Museu de Zoologia da Universidade de São Paulo/Universidade Federal do Pará/Museu de Zoologia da Universidade Estadual de Campinas, São Paulo/Campinas, Brazil, 400 pp.

Pouilly M, Yunoki T, Rosales C, Torres L (2004) Trophic structure of fish assemblages from Mamoré River floodplain lakes (Bolivia). Ecology of Freshwater Fish 13 (4): 245–257. https://doi.org/10.1111/j.1600-0633.2004.00055.x

Py-Daniel LHR, Deus CP, Ribeiro OM, Sousa LM (2007) Peixes. In: Py-Daniel LHR, Deus CP, Henriques AL (Eds.) Biodiversidade do médio Madeira: bases científicas para propostas de conservação. Instituto Nacional de Pesquisas da Amazônia, Manaus, Brazil, 89–125.

Queiroz LJ, Torrente-Vilara G, Ohara WM, Pires THS, Zuanon J, Doria CRC (2013) Peixes do Rio Madeira. Editora Dialeto, São Paulo, Brazil, 1163 pp.

Reis RE, Albert JS, Di Dario F, Mincarone MM, Petry P, Rocha LA (2017) Fish biodiversity and conservation in South America. Journal of Fish Biology 90 (4): 1191–1195. https://doi.org/10.1111/jfb.13016

Rezende CF, Mazzoni R (2003) Aspectos da alimentação de *Bryconamericus microcephalus* (Characiformes, Tetragonopterinae) no Córrego Andorinha, Ilha Grande–RJ. Biota Neotropica 3 (1): 1–6. https://doi.org/10.1590/S1676-06032003000100012

Roach KA, Winemiller KO (2015) Hydrologic regime and turbidity influence entrance of terrestrial material into river food webs. Canadian Journal of Fisheries and Aquatic Sciences 72 (7): 1099–1112. https://doi.org/10.1139/cjfas-2014-0459

Santos GM, Ferreira EJ (1999) Peixes da bacia amazônica. In: Lowe-McConnell RH (Ed.) Estudos ecológicos em comunidades de peixes tropicais. EDUSP, São Paulo, Brazil, 349–354.

Silva RSD, Corrêa F, Oliveira LPD, Guerra V, Barros BS, Vieira LJS (2020) Ictiofauna de praias arenosas ao longo do rio Acre, Brasil. Biota Neotropica 20 (3): 12–24. https://doi.org/10.1590/1676-0611-bn-2020-0988

Silva RS, Corrêa F, de Oliveira LP, Vieira LJ (2019) Length–weight relation of the 14 fish species occurring on sandy beaches along a tropical river in the Amazon. Journal of Applied Ichthyology 35 (2): 622–624. https://doi.org/10.1111/jai.13852

Silvano RAM, Oyakawa TO, Amaral BD, Begossi A (2001) Peixes do Alto Rio Juruá (Amazonas, Brasil). EDUSP, São Paulo, Brazil, 187 pp.

Sioli H (1984) The Amazon and its main affluents: hydrography, morphology of the river courses, and river types. Springer, Dordrecht, the Netherlands, 165 pp.

Stewart DJ, Ibarra M, Barriga-Salazar R (2002) Comparison of deep-river and adjacent sandy-beach fish assemblages in the Napo River basin, eastern Ecuador. Copeia 2002 (2): 333–343. https://doi.org/10.1643/0045-8511(2002)002[0333:codraa]2.0.co;2

Vieira FG, Matsuzaki AA, Barros BSF, Ohara WM, Paixão AC, Torrente-Vilara G, Zuanon J, Doria CRC (2016) Catálogo de Peixes da Estação Ecológica de Cuniã. EDUFRO, Porto Velho, Brazil, 158 pp.

Whitehouse GA, Buckley TW, Danielson SL (2017) Diet compositions and trophic guild structure of the eastern Chukchi Sea demersal fish community. Deep Sea Research Part II: Topical Studies in Oceanography 135: 95–110. https://doi.org/10.1016/j.dsr2.2016.03.010